

Electricity Generation from Biogas of Cassava using Cattle Manure as inoculum: An Assessment of Potential in the Quilombola Community (Brazil)

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Abstract— The bioenergy has turned into a good alternative for reducing the emission of pollutant gases. In Brazil, the use of this type of energy has increased in the last decades. Biogas, produced from cassava, appears as an alternative fuel to fossil fuels and, also, becomes economically competitive, since this is a low cost carbon source. Anaerobic biodigesters that use renewable raw materials are known as a technology with great potential for biogas production which is considered a source of clean energy. Biogas produces sustainable energy and consists mainly of methane (60%) and carbon dioxide (35% to 40%). This study presents the biogas potential from the cassava processing residual water for the production of dry flour (manipueira). The results of this study indicated that the biogas potential is 1.389.312 cm³ per year from a single-stage reactor with a capacity of 60 liters using manipueira as substrate and inoculated with cattle manure, which could provide a generation of electricity of 214 kwh/year.

Keywords— Biogas, Cattle Manure, Quilombola Community.

I. INTRODUCTION

Several quilombola communities do not have access to electricity due to the cost of distribution and territorial difficulties. Alternatively, many of these communities adopt isolated power generation systems that typically adopt renewable sources such as solar, biogas, wind or internal combustion. Although these communities have access to electricity, much of the community, in general, has no purchasing power to use this type of energy freely.

On the other hand a strong characteristic of these quilombola communities and the production of different types of biomass. Considering that biomass is the raw material for the production of biogas, the use of biodigester for the production of electric energy is a good alternative for the production of electric energy, considering that small generators are able to convert biogas into electric energy.

The intensive depletion of fossil fuel resources due to their huge utilization with the abrupt fluctuation in oil and fossil fuel energy source prices has led to increasing trends towards finding renewable and cost-wise green energy alternatives (Abdeshahian *et al.*, 2014). On the other hand, the greenhouse gases (GHG) act as a determinant factor in global warming by surrounding the heat reflected from the earth surface with the highest contribution of CO₂(60%) and less effect of CH₄ (15%) (RAHIMNEJAD *et al.*, 2015).

In this way, the development of sustainable technologies for the production of bioenergy has become an attractive alternative for the energy sector regarding reduction of pollutant emissions. The need to change the energy matrix, due to several factors, has provided great incentive for the insertion of this form of energy generation in Brazil and many countries around the world (MADEIRA *et al.*, 2017a).

The production of biogas through Anaerobic Digestion (AD) offers significant advantages over other forms of bioenergy production. It has been evaluated as one of the most energy-efficient and environmentally beneficial technology for bioenergy production (FEHRENBACH *et al.*, 2008). Biogas generation can drastically reduce greenhouse gases compared to fossil fuels by utilization of locally available resources. The digestate represents an improved soil conditioner which can substitute mineral fertilizer (WEILAND, 2010).

Many studies have been made on the AD process of biogas production using different biomass as mono-substrates (KHALID *et al.*, 2011; BABAEE *et al.*, 2013; SALMINEN and RINTALA., 2002). The major problem of the direct use of substrates is the fate of certain anaerobic bacteria and the low diversity of nutrients. The co-digestion process was recommended to overcome the difficulty, like mixing agricultural byproduct with cattle manure (MATA-ALVAREZ *et al.*, 2000).

Cassava wastewater is a byproduct of the cassava processing plant, an effluent with high potential for biohydrogen production. Its potential for energy production has gained strength in the last years (ANYANWU *et al.*, 2015; CHALEOMRUM *et al.*, 2014; MADEIRA *et al.*, 2017b). Cassava wastewater exhibits high polluting effects due to the increased BOD level and for containing hydrocyanic acid, which makes this residue different from others of the agroindustry (FIORETTO, 1994). According to LACERDA (1991), this toxicity from cyanidric acid is attenuated, because in his studies on the kinetics of the methanogenic phase, using cassava

wastewater as the substrate, concluded that the removal of cyanide obtained 37.5% of efficiency.

The AD of manipueira due to high starch concentration is impaired by a slow rate of methanogenesis which generally acidifies the substrate. An alternative to avoid acidification of the process is the use of inoculum, because at the beginning of the AD process the amount of acids and hydrogen is higher as a function of the rate of generation of the acid forming bacteria, the addition of a sufficient amount of methanogenic organisms, through the use of the inoculum, can prevent imbalance.

II. MATERIALS AND METHODS

2.1. Study site

The municipality of Angra dos Reis is located in the state of Rio de Janeiro, located over the Southeastern part of Brazil as shown in Figure 1. The municipality has a territorial area of 825,082 km² and a population of approximately 184,940 inhabitants (IBGE, 2014).

The project was created and implemented in the Quilombo de Santa Rita, located in the municipality of Angra dos Reis, located at latitude 22°54'2.322 "S and longitude 44°24'48.895" W, as shown in Figure 1. This village is made up of approximately 110 families of which, a significant part, exclusively develops rural activity for their subsistence. It is a village with characteristics determined by the historical formation of the municipality, where the quilombos express the memory of Afrodescendant culture, maintaining cultural traditions of religion, dance, subsistence, and other manifestations (REIS 2013).



Fig.1: Location map for Angra dos Reis

In his will, opened in 1879 nine years before the abolition of slavery, the Commander Breves freed all his slaves and made a formal donation of the property for those who were living in Bracuí, that is, ancestors of current residents of the community. Despite the donation, since the 1960s the "quilombolas" struggle against land grabbers and try to avoid the construction of luxury condominiums so they can stay on the land inherited by law (PMAR, 2018).

The raw materials that constituted the present study were: manipueira (substrate); cattle manure (inoculum). The cattle manure and the residue of the production process of cassava flour (manipueira) used in the present study was obtained in the Quilombola

community, due to the high production of manipueira for subsistence and the creation of horses throughout the whole Quilombo.

2.2. Biodigester construction

The manipueira, used as substrate, was mixed with cattle manure, used as inoculum and the ratio used, respectively, was 75% and 25%. The biodigester constructed was a discontinuous flow digester (single-stage reactor). Each batch biodigester was composed for just one container: digestion chamber (70 liters), net digester volume (60 liters), the remaining 10 liters accumulate the gas, functioning as a gasometer, as described in Figure 2.



Fig.2: Single-stage reactor with a capacity of 70 liters

In the lid of the digestion chamber was installed a copper pipe to rubber tube gas valve (biogas outlet), this pipe connect the digestion chamber to a stove burner gas mouth. This camping stove has been adapted because the gas outlet hole has less than 1mm of diameter, which does not allow the flow of the biogas, since it is under low pressure. In this way the hole diameter was enlarged to 5mm, allowing the gas flow efficiently.

The average temperature of the biodigesters along the hydraulic retention time (HRT) was 28 ° C and twice a week 30 ml of biogas was collected for characterization. For the storage of the biogas to the laboratory where the characterizations of the biogas were carried out, it was necessary to prepare vials for the storage and transportation of biogas. The Penicillin vials was sealed

and had its internal volume filled with sealing liquid prepared according to DIN 38414-8 (DIN, 1985) (solution consisting of 30 mL of sulfuric acid, 200 g of sodium sulfate decahydrate and some drops of methyl orange gauge). The biogas characterization was performed at the Biomass and Water Management Research Center, Fluminense Federal University, from a gas chromatograph (GC-FID / TCD Agilent, model 7890B).

2.3. Calculation of the potential of electric energy generation from biogas

For the calculation of heating value of the methane generated, it was assumed that 85% (efficiency) of the methane evolved could be converted to heat (ABDESHAHIAN *et al.*, 2016) in the boiler by

considering a calorific value of 36 MJ per cubic meter of methane (36 MJ/m³) (FBHEF, 2018).

The potential of electricity generation from the biogas was calculated according to Equation 1:

$$e_{biogas} = E_{biogas} \cdot \eta \quad (1)$$

Where:

e_{biogas} : quantity of generated electricity (kWh/year);

E_{biogas} : unconverted raw energy in the biogas (kWh/year);

η : denotes the overall efficiency of the conversion of biogas to electricity (%).

The parameter η varies according to the power generation plants. The η value is considered from 35 to 42% and 25% in the power plants with large turbine system and small generators, respectively (BENITO *et al.*, 2015). In this study, the η value was assumed as 25%, because the capacity of the biodigester used is small. The quantity of E_{biogas} : is calculated using Equation 2:

$$E_{biogas} = LHV_{biogas} \cdot \dot{m}_{biogas} \quad (2)$$

Where:

LHV_{biogas} : calorific value of biogas (kWh/m³);

\dot{m}_{biogas} : amount of biogas produced per year (m³/year).

In this equation, the LHV of the biogas is considered as the LHV of the methane multiplied by the percentage of methane contained in each of the biogases, as described by Equation 3:

$$LHV_{biogas} = P_{ch4} \cdot LHV_{ch4} \quad (3)$$

Where:

P_{ch4} : percentage of methane contained in biogas (%);

LHV_{ch4} : calorific value of methane (kWh/m³).

The LHV_{CH4} used was 9,9519 (kWh/m³) (Braga *et al.*, 2013). The biodigester's operating time was approximately one month, which is equivalent to 12 batch per year, so from a production reference of 0.115776 m³/month per month, so it is possible to estimate the production of 1.389312 m³/year.

III. RESULTS AND DISCUSSION

A small fraction of inoculum can generate biogas. This is due to the fact that even though the cattle manure is important due to the large amounts of anaerobic microorganisms in the digestive tract of these animals, but excess of lignin present in ruminant animals manure disrupt methane production and thereby decrease biogas production and consequently produce poor quality biogas (low CH₄ concentration).

Ruminant's manure have significant amount of lignin (Table 3), which is a phenolic compound of difficult degradability and when complexed with cellulose and hemicellulose not allow conversion of these compounds in precursors of biogas [20-23]. In this way, it was predicted that excess cattle manure could disrupt the biodigestion process

Another parameter that also contributes to a low inoculum ratio used is the Carbon/Nitrogen (C/N) ratio, as shown in Table 1. According to literature it is recommended that the C/N ratio in substrate be in the range of 25-30 for the anaerobic digestion process. [17].

Table 1: C/N ratio, lignin, hemicellulose and cellulose concentration.

Inoculum / Substrate	C/N	Cellulose (g/kg)	Hemicellulose (g/kg)	Lignin (g/kg)
Livestock manure	13.9 [16]	110 [18]	80 [18]	140 [18]
Cassava	19 [17]	250 [19]	70 [19]	30 [19]

The biodigester produced gas with an average concentration of 62% and the accumulation of biogas volume was 115,776 cm³. The Figure 3 shows the volume of biogas produced during the HRT.

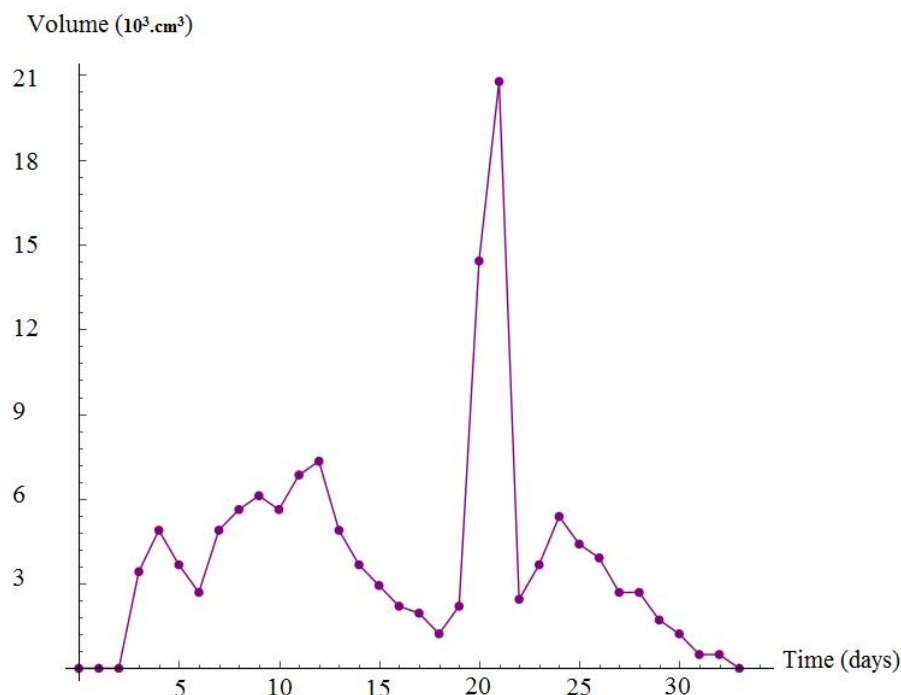


Fig.3: Volume of biogas produced in the biodigester under study along the HRT

The produced biogas can be converted into electrical energy from a small generator. The 60 liter biodigester of net value is capable of generating 2.14 kwh/year. In Table 2 we can see the comparative of the energy produced applied to some electronic devices.

Table 2: Days of operation using the energy provided by a small generator fed by the biogas under study

Description	Assumed daily time (hours)	Operating energy (Wh/dia)	Days of operation using the energy provided by a small generator fed by the biogas under study
Computers (laptop)	3	203.07	10.55
Home audio	3	165.93	12.91
Televisions (CRT)	3	150.78	14.21
Televisions (LCD)	3	490.23	4.37
Microwave ovens	0.34	150.28	14.26
Washing machines	0.5	375	5.71
Electric shower	0.67	1571.15	1.36
Fan	8	6400	0.33
Refrigerator	24	115200	0.02

Table adapted from GUAN et al. 2011.

IV. CONCLUSION

The inoculation of manipueira with cattle manure presented satisfactory results, because with a small amount (close to 25%) of inoculum, it was possible to create a biodigester with a satisfactory biogas recipe and a percentage of methane sufficient to create a flammable biogas. A biodigester with a capacity of 60 liters is able to produce enough biogas, which converted into electricity, is capable of supplying small electrical devices. However for electricity production to become viable, ideally a

larger capacity biodigester or several biodigesters connected in series should be used.

There are several studies related to the production of biogas from the manipueira, however, in general, in these studies, single-stage reactors are used, because the AD of manipueira due to high starch concentration is impaired by a slow rate of methanogenesis which generally acidifies the substrate. A small amount of manure inoculates the substrate with the intestinal

bacteria of the animals and does not present enough lignin to acidify the substrate.

Thus, single-stage reactors can be used to produce biogas and/or electricity using manipueira as substrate, but efficient production of electricity, biodigestors that operate with large volumes of substrate are recommended.

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